ICs for Telecom

Measures to meet EMC requirements for TEA 1060-family speech transmission circuits

Author: Mart Coenen
Klaas Wortel
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Abstract

Recently the ElectroMagnetic Compatibility (EMC) of the TEA 1060-family, speech/transmission circuits, have been investigated again. If a few components are placed at the right spots the TEA 1060 circuits reach a good performance. This report describes the measures which can be taken without influencing the basic functioning of the IC.

Measures to meet EMC requirements for TEA 1060-family speech transmission circuits

Mart Coenen
Klaas Wortel

Philips Components Application Laboratory Eindhoven, the Netherlands.

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Summary

Electromagnetic compatibility (EMC) has become an important issue for electronic telephone sets since more and more PTTs come up with EMC-requirements. In 1986 an external report ETT 8613 was issued about the EMC for our TEA 1068 speech transmission circuit. The report contained some application and PCB layout hints. The information needed to be updated since it had shown to be inadequate for all our customer applications with the topical requirements.

The study was extended for the entire family TEA 1060/61/67/68 and better solutions were found which have shown their validity in many customer applications.
For immunity testing the current injection method is used according the German requirements, VDE 0878 part 200 (draft 1986), which can also be found in the draft IEC publication 801/6 "Conducted immunity requirements".

The outcome of the investigations shows that by adding a few components at the right places, the TEA 1060-applications satisfy the EMC-requirements. The influence of these components on the functioning of the IC are not always negligible and are discussed in this report.
Other not allowed solutions, found in several customer applications, are listed too.

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1. Introduction

Many of todays electronic apparatus have to be used in a RF-signal polluted environment. The number of wireless communication paths has increased quite rapidly for various applications e.g. : national broadcasting for radio and television, citizen band, short-wave communication, beacons, Radio amateurs, and cellular telephone. They cover the frequency spectrum from 10 kHz up to 1 GHz and above.

The transmitted energy of such devices may be quite large or the distance between the RF-source and other equipment may be quite small and may become a source of interference to other kinds of apparatus such as a common electronic telephone set.

Many Postoffices and/or National Authorities have defined requirements with respect to the functional specifications of the telephone sets. With respect to EMC (ElectroMagnetic Compatibility) no common European or International specification exists (yet) and the individual standards does not make it much easier.

The existing immunity test methods can be divided in three main groups:

- differential mode current injection,
- electromagnetic field generated by a strip-line (TEM-cell),
- common mode current injection,

and commonly cover the frequency range from 10 kHz up to 150 (200) MHz.

A test method is incomplete without defining the limits with respect to the demodulated signal towards the a,b-lines or the earpiece capsule to which the demodulation becomes discernable. Here again the methods can be divided in two main groups:

- acoustic measurements (measuring SPL or dBPa) or
  electrical measurements across the earpiece capsule,
- electrical measurements on the a,b-lines

and the required S/I-ratio (signal-to-interference ratio) may vary between 26 - 40 dB. The nominal signal (send and/or receive) level at 1 kHz is set at 100 mV across the telephone line impedance, $\simeq 600\ \Omega$.

In order to satisfy the most stringent requirements, the German proposal was adopted to verify the immunity performance of our TEA 1060 applications.

2. Immunity test system

The printed circuit boards on which the speech transmission ICs are used in their applications are commonly small compared to the wavelengths of the applied interference signals (frequency < 300 MHz $\div$ λ > 1 meter). The traces on the printed circuit board should be kept small (< 1/10) compared to this wavelength to ensure that direct pick-up will be negligible.
In this situation the only part of the telephone set capable of acting as an antenna in order to receive a part of the interference signal will be the leads towards the public telephone network on one hand and the leads towards the handset on the other.

When the telephone set is placed in a strip-line (or TEM-cell), the RF-induced signal will be highly sensitive to the geometry of these leads, while during the current injection test these geometric constraints are excluded.

2.1. ElectroMagnetic field

With a parallel strip-line a plane-wave electromagnetic field is generated between the two (or three) flat conductors being the transmission line. The generated electric fieldstrength is equal to the voltage between the conductors divided by the distance between them.

The telephone set with its handset and its leads to the public telephone network receive this RF-field. The induced signal at low frequencies will be low due to the un-efficiency of the "antenna" (lead length) which is present between the two planes. At higher frequencies the value of the induced signal will show resonances due to the geometry of the set-up between the planes. Furthermore, the resonant frequencies will vary with the geometry and within a reasonable test sequence no "worst-case" response can be found.

2.2. Current injection

As explained above, the test set-up geometry may have a large impact on the results obtained and for reproduceability sake these kind of tests should be avoided.
With the current injection method the interfering signal is directly applied to the telephone set as a common-mode signal. The common-mode impedance of the source is chosen to be an "average" of 150 Ω [1].
Therefore, coupling networks (CI-networks) have to be placed between the 50 Ω RF-generator and the telephone set under test. The telephone set with the handset are placed on a non-metallic support of 100 mm height above a metallic reference plane on which the coupling networks are mounted. The lead length of the a,b-lines, between the public telephone coupling network, known as T-network, and the telephone set, should be limited to 300 mm. This to avoid resonances due to the geometry (lead length) of the test set-up. The handset should be wrapped in copper foil and this should be connected to reference by a series-impedance of 500 Ω + 200 pF, known as the artificial hand [2].

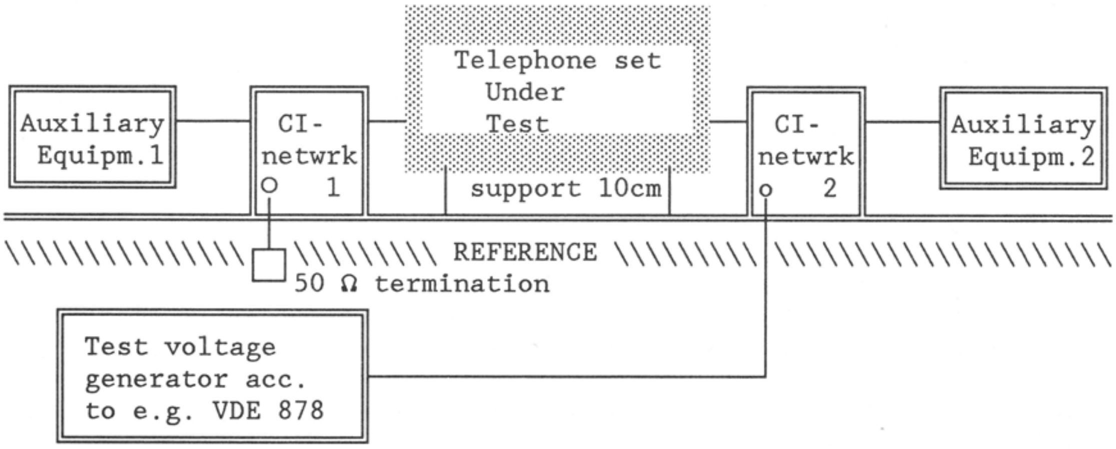


Figure 1. Schematic set-up for the current injection test.

The RF-signal is an amplitude modulated signal. The modulation depth is 80 % and the modulating frequency is 1 kHz.

By forcing the RF-current to flow through that telephone set under test, the direct immunity is tested as well as the immunity to RF-fields due to the re-radiation caused by that current.

Measurements have shown that sets complying with the current injection method at normal RF-signal levels indicated in table 1, column "normal" gave an immunity to EM-fields, under the same S/I-criteria, of 10 Volt/meter and higher.

Frequency range MHz	Applied voltage	
	normal	enhanced
.01- .1	1.5	1.5
.1-30	3.0	6.0
30-150	.5	1.5

Table 1. The RF-signal levels that have to be applied to the telephone set under test.

3. Measures to improve the basic EMC performance (M1)

This section discusses the measures to improve the EMC performance of the speech and transmission ICs and the effect of the extra EMC components on the basic functioning of the TEA 1060-applications as described in report ETT 8613. The five capacitors at IR, MIC, LN and V_{CC} have improved the application quite a bit, but according to the more stringent requirements other necessary measures needed to be taken. The immunity performance of the TEA 1060 applications with respect to the basic EMC measures, see annex 1, with this current injection method and normal RF-levels which are used throughout this evaluation, is given in annex 2a); detection on the a,b-lines, and 2b); detection at the earpiece side.

First the measures at the microphone input, the earpiece output pins and the connection to the a,b-lines are discussed. The measures to improve immunity are given in annex 3, and the EMC-performance is given in annex 4a, detection on the a,b-lines, 4b, detection at the earpiece side.

3.1. Practical implementation

The RF-signals are mainly picked up by the leads connected to the telephone base set, see figure 2. The easiest way to overcome unwanted demodulation is to let the RF-induced current flow through an extra conductor instead of through the reference of the telephone circuitry.
Care must be taken that the re-radiation of the RF-currents through this extra conductor will not be picked up by the telephone circuitry again. Therefore an open space must be made between the circuitry and this conductor to reduce mutual coupling between the two. No long wires, which run over the PCB may be used for this connection !!

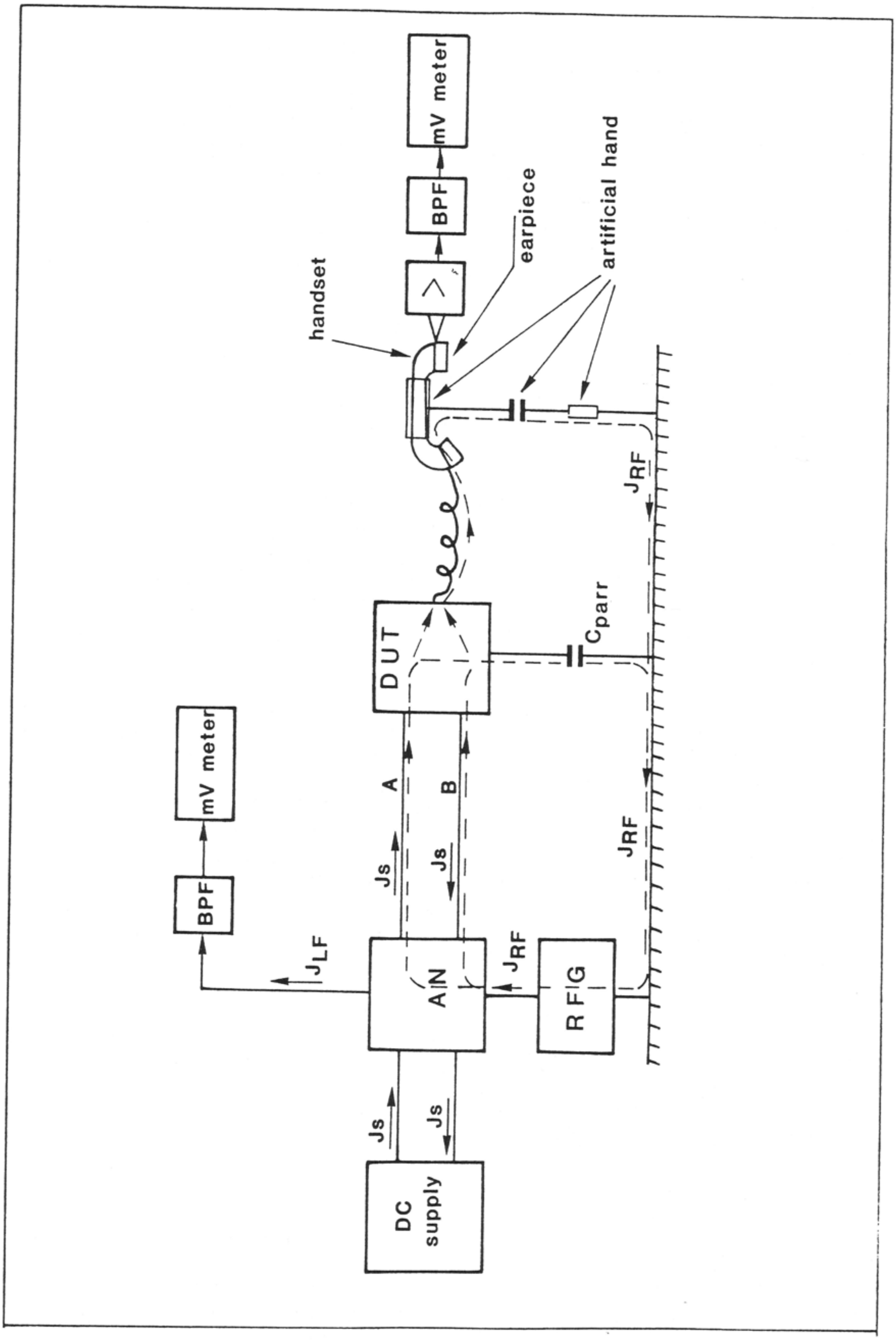
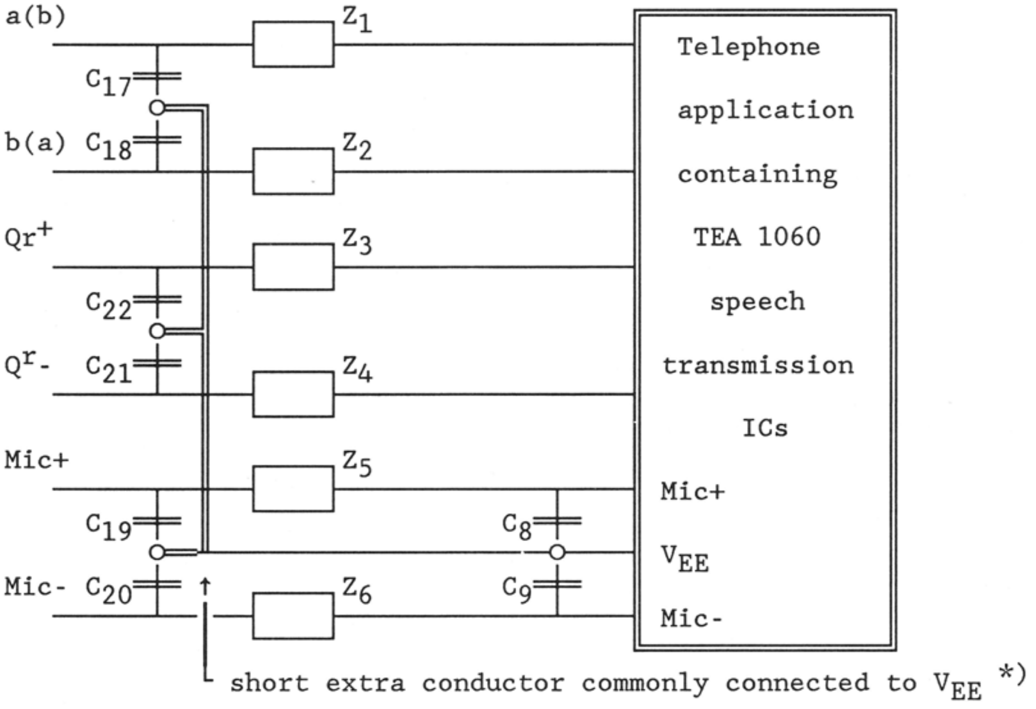


Figure 2. RF-current flow through the telephone application according to the chosen test method.



*) If other peripherals of the application are used, the same network must be continued.

Figure 3. The modified circuit to improve the immunity of Telephone sets containing TEA 1060-family speech transmission IC (see also annex 3 and 5).

The effect of these measures on functionality will be discussed in the next paragraphs.

3.1.1. Microphone inputs:

To prevent demodulation of the RF-injected signals in the microphone stage extra filters at the input must be applied:

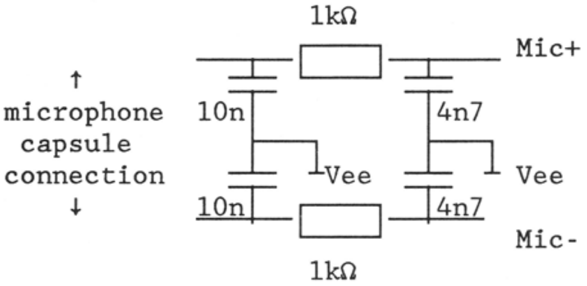


Figure 4. "Extra filtering at microphone inputs"

The 10nF capacitors decouple the RF-signal entering via the handset cord. The RF-signal which is then still present is filtered by means of the 1kΩ resistors and 4n7 capacitors.

cut-off frequency: 33.86kHz

As regards frequency dependence the extra filter does not have a noticeable influence on sending gain for frequencies between 300 and 3400Hz.

However, since the input impedance of the microphone amplifier is not infinite attenuation occurs. And due to the fact that the input impedance has a certain tolerance the attenuation shows a tolerance also. This means extra tolerance on the gain setting occurs!
In table 2, the attenuation, impedance and their tolerance are shown for several types of the TEA 1060 family:

	minimum	typical	maximum	
TEA 1060 input impedance:	3.3	4.1	4.9	kΩ
Attenuation with 1kΩ:	-2.30	-1.90	-1.61	dB
extra tolerance:	-0.29		+0.40	dB
TEA 1061 input impedance:	16.5	20.4	24.3	kΩ
Attenuation with 1kΩ:	0.51	0.42	0.35	dB
extra tolerance:	-0.10		+0.07	dB
TEA 1067/68 input impedance:	25.5	32.0	38.5	kΩ
Attenuation with 1kΩ:	0.33	0.27	0.22	dB
extra tolerance:	-0.05		+0.06	dB

Table 2. Gain and impedance tolerances due to the RF-immunity measures

The extra tolerance on the sending gain for TEA 1061/67/68 of less then 0.1 dB seems acceptable, but for the TEA 1060 the extra tolerance is rather high. With a 180Ω resistor (increase 4n7 to 27n for same cut off frequency) instead of the 1kΩ for the TEA 1060 the extra tolerance on sending gain is less then 0.1 dB which is in line with the rest of the family.

3.1.2. Earpiece outputs

For the earpiece outputs also filtering is applied to prevent RF-signals to enter the internal TEA 1060 circuitry:

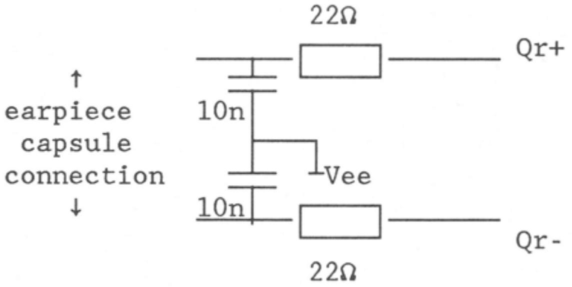


Figure 5. "Extra filtering at earpiece outputs"

The 10nF capacitors first decouple the handset cord. The 22Ω resistors attenuate the RF-signal which is still left. Since demodulation in a non linear device as a transistor has a quadratic relationship with the applied level, only little RF-attenuation will improve a lot.

The filter from Qr to the earpiece has no influence on speech signals between 300-3400Hz, cut-off frequency: 723kHz.

The disadvantage of the extra components for LF:

1. Receiving gain decreases
2. Maximum output level decreases

The actual influence is dependent on the impedance of the earpiece.

Example:
Influence gain + max output level: (ignore small change Qr+ level for max output)

150Ω single ended: -1.19 dB

450Ω bridge tied load: -0.81 dB

The effect on gain can easily be compensated (increase resistor between Qr+ and GAR in basic application) but the effect on maximum output level will remain.

3.1.3. Telephone line:

In front of the diode bridge 2 extra decoupling capacitors are desired to prevent RF-signals to enter the TEA 1060 (see figure).
For the application this means care has to be taken with Balance return loss. With a 600Ω set impedance still more than 20dB of BRL (balance return loss) can be reached if 10nF is present at the line.
Since the two 4n7 capacitors form a load at the line of only 2n35 still 1-6n8 can be connected to pin LN of the TEA 1060 after the diode bridge.

The coil after the diode bridge will form a high impedance at high frequencies forcing decoupling via the line capacitors rather than through the TEA 1060.
For audio frequencies the influence of the coil can be neglected, but its low frequency series resistance should be as low as possible!

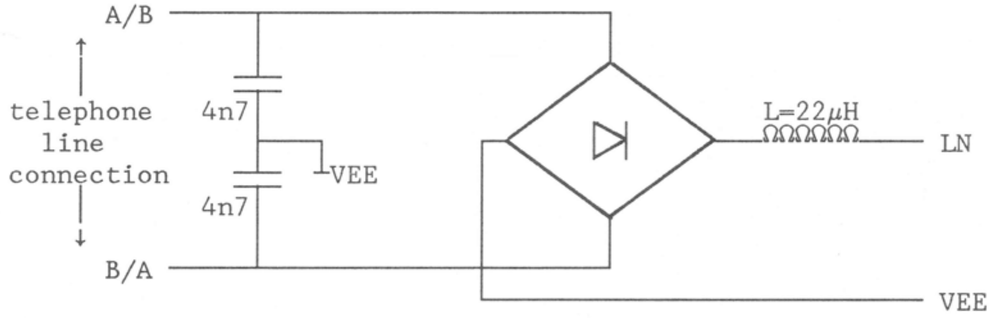


Figure 6. "Extra filtering at a,b-lines"

3.2. Conclusions

The following measures to improve the RF-immunity can be taken without influencing the TEA 1060-family functioning too muchon the common application board CAB 3391, see annex 7:

Microphone inputs:

- Microphone cord decoupling: 2 x 10nF
- Series resistors : 2 x 180Ω (TEA 1060 only), 2 x 1kΩ (rest)
- Mic. inputs decoupling : 2 x 27 nF (TEA 1060), 2 x 4.7nF (rest)

Receiver outputs:

- Earpiece series resistors: 2 x 22Ω
- Earpiece cord decoupling : 2 x 10nF

Telephone line:

- Telephone line decoupling in front of diode bridge: 2 x 4n7
- Series inductor after diode bridge : 1 x 22μH
- reduction of C_{LN} from 10 nF to : 1 x 5n6

4. Measures to reach enhanced immunity (M2)

Some problems remain with respect to the internal reference (SLPE) which is used inside the speech transmission IC. The transmission stage of the TEA 1060 may demodulate the RF-signal into a 1 kHz base band signal which can be measured on the a,b-lines. The side-tone network couples this signal to the input of the receiving amplifier. This signal then, becomes audible at the earpiece side.

4.1. Output stage:

The EMC measures which have to be taken at the output stage need to be chosen properly because the output stage can become instable.

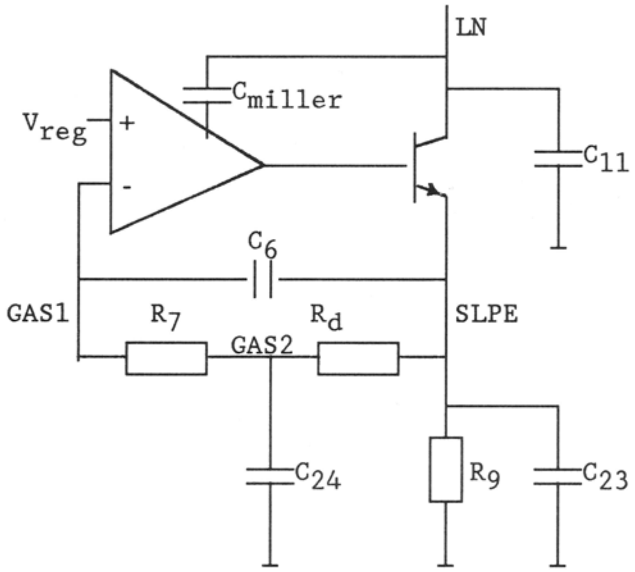


Figure 7. Transmission stage of the TEA 1060

From this network the ranges for the values of the capacitances at the pins: SLPE, GAS1, GAS2 and LN have been optimised to improve the RF-immunity without affecting the stability of the circuit.

Optimal selection of the capacitors:

* C_6 = 100pF minimum, larger values can be used for High Frequency roll-off of the transmission amplifier.

* C_{24} = 100pF maximum for all possible applications.

$$\text{typ. } C_{24} \ll \frac{(R_7 + R_d).C_6}{R_d}$$

* C_{11} = 1 to 10nF, larger values are not practical with respect to the BRL!

* C_{23} = 220pF maximum.

4.2. Conclusion

The immunity of the TEA 1060-family can be further improved by adding 2 capacitors; C_{24} = 100 pF, C_{23} = 220 pF, see annex 5. The results on the immunity can be found in annex 6a, for the detection on the a,b-lines and 6b, for the detection at the earpiece side.

5. Other measures

5.1. Do:

* Apply series resistors (> 1 kΩ) with the DTMF, PD, MUTE lines between the dialer or μP and the speech transmission IC.

* Place R_{SLPE}, R_{STAB} as close as possible to the TEA 1060

* Place C_{REG}, C_{IR}, C_{MIC}s and C_{LN} as close as possible to the TEA 1060

* Make a ground loop around the TEA 1060 but avoid other then functional currents to run through this loop!

5.2. Don't:

* Connect large circuit parts to SLPE without decoupling capacitor C_9

* Decouple e.g. LN or IR at several reference points on your PCB without any series impedances. It will cause resonances with the copper trace inductances with high Q-factors.

* Apply a capacitor in parallel to R_{STAB}. It will lower the phase margin at lower frequencies (1-5 MHz).

6. Conclusion

The final result of the measures partly depends on the remaining part of the circuitry connected to the TEA 1060. This because the performance of the IC has been tested mainly on its application board, while commonly other circuit parts will highly influence the RF-current distribution throughout the telephone set.

With the above described measures it is possible to create a telephone set application which will give at least a S/I-ratio of 26 to 40 dB both at the a,b-lines and at the earpiece-side in the entire frequency range 100 kHz up to 150 MHz under "normal" RF-severity levels.

Reproduceability of the results obtained from the test set-up which is further explained in VDE 0878 [3] has shown to be within a few dBs (≤ 3).

7. References

[1.] IEC CISPR publication 20,
[2.] IEC CISPR publication 16,
[3.] VDE 0878 part 1 and 200, 1987.

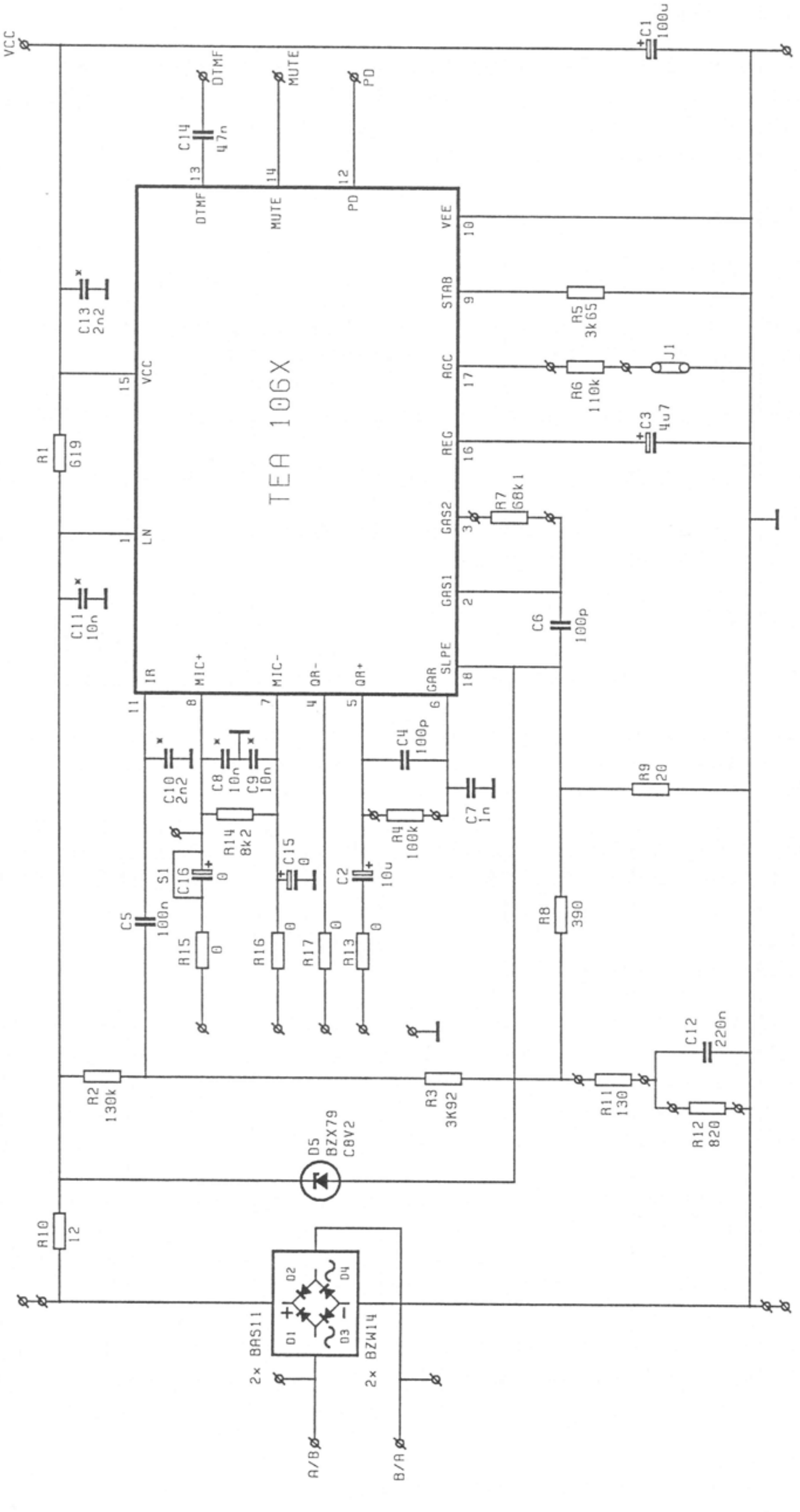
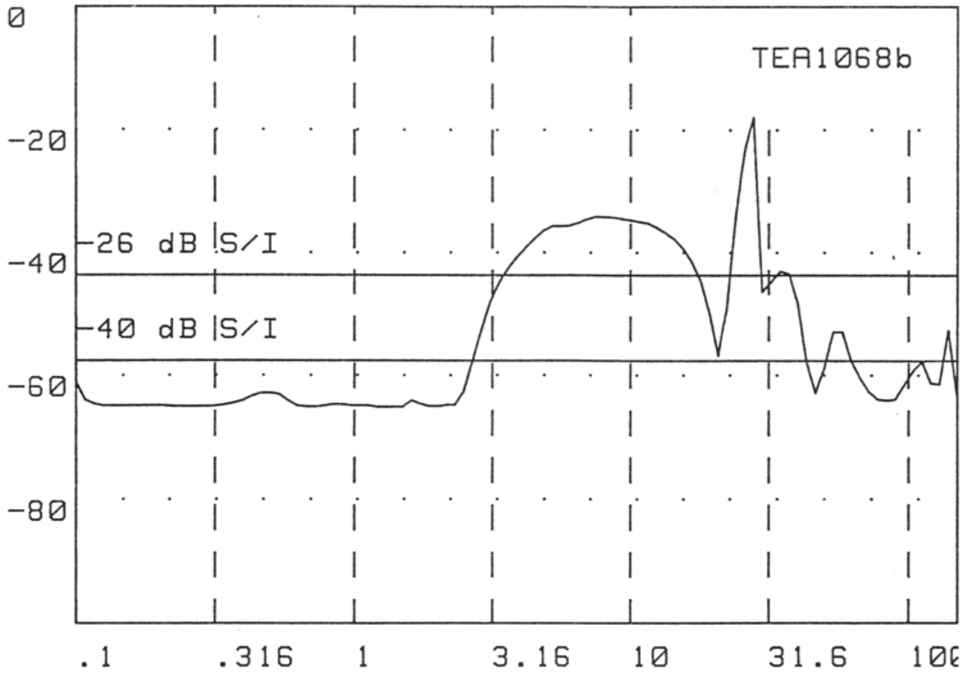


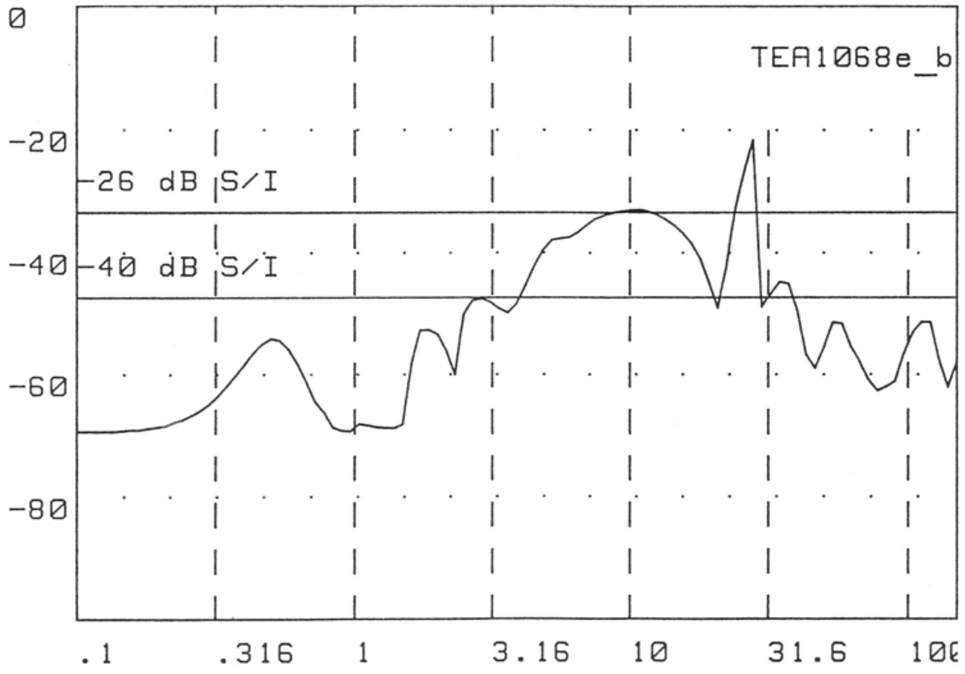
Fig. 1 CIRCUIT DIAGRAM OF PRINTED CIRCUIT BOARD CAB3391

(Note : Capacitors with capacitance 0 are not mounted.
Resistors with resistance 0 and coils with
inductance 0 are replaced by a short.
Capacitors marked '*' are used to provide basic EMC)

Annex 1 TEA 1060 application with 'basic' EMC performance
(add 5 capacitors)



a) detection on a,b-lines



b) detection at earpiece side.

Annex 2 EMC performance of basic application.

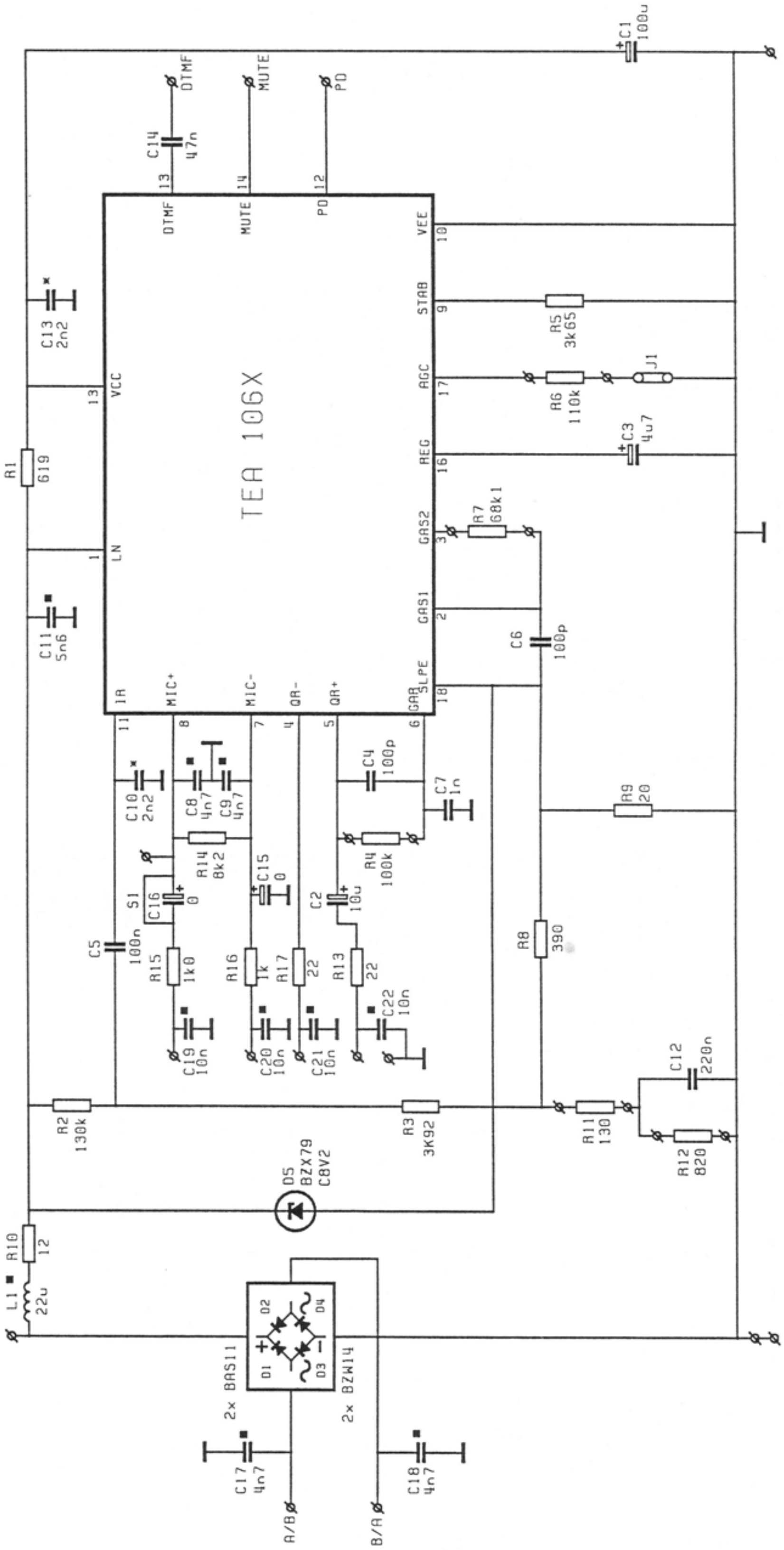
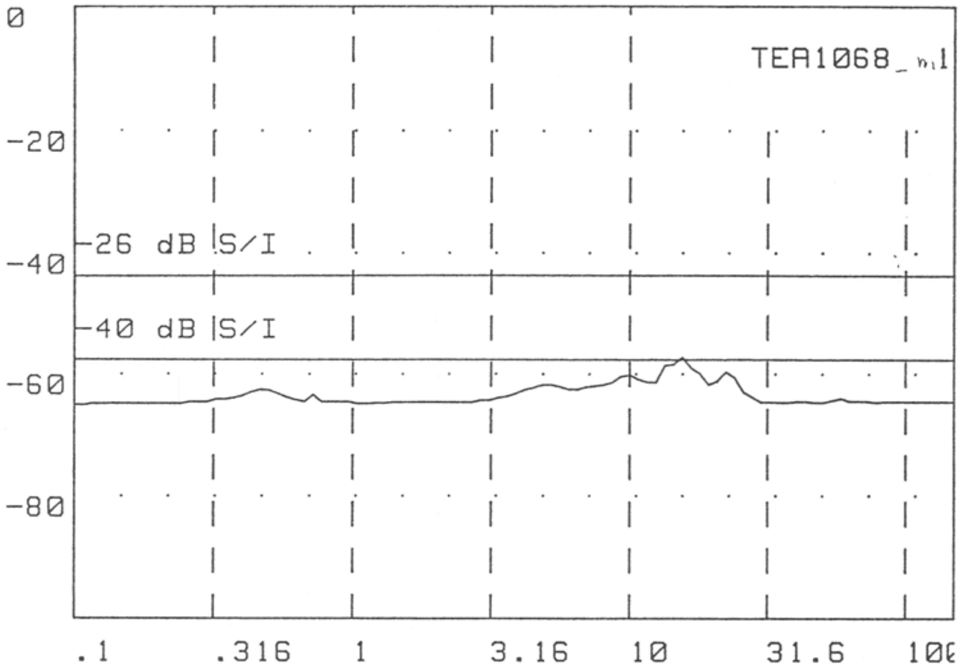


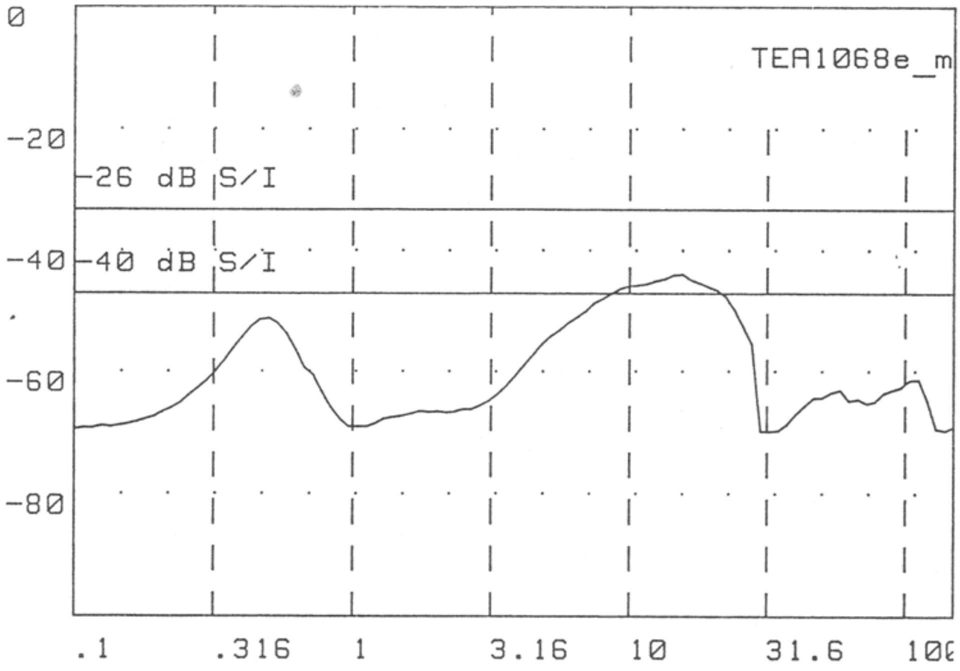
Fig. 2 CIRCUIT DIAGRAM OF PRINTED CIRCUIT BOARD CAB3391 (Mod.1)

(Note : Capacitors with capacitance 0 are not mounted.
Resistors with resistance 0 and coils with
Inductance 0 are replaced by a short.
Components marked '■' are used to improve basic EMC)

Annex 3 TEA 1060 application with 'improved' EMC (M1) performance (add 11 components)



a) detection on a,b-lines



b) detection at earpiece side.

Annex 4 EMC performance of improved application.

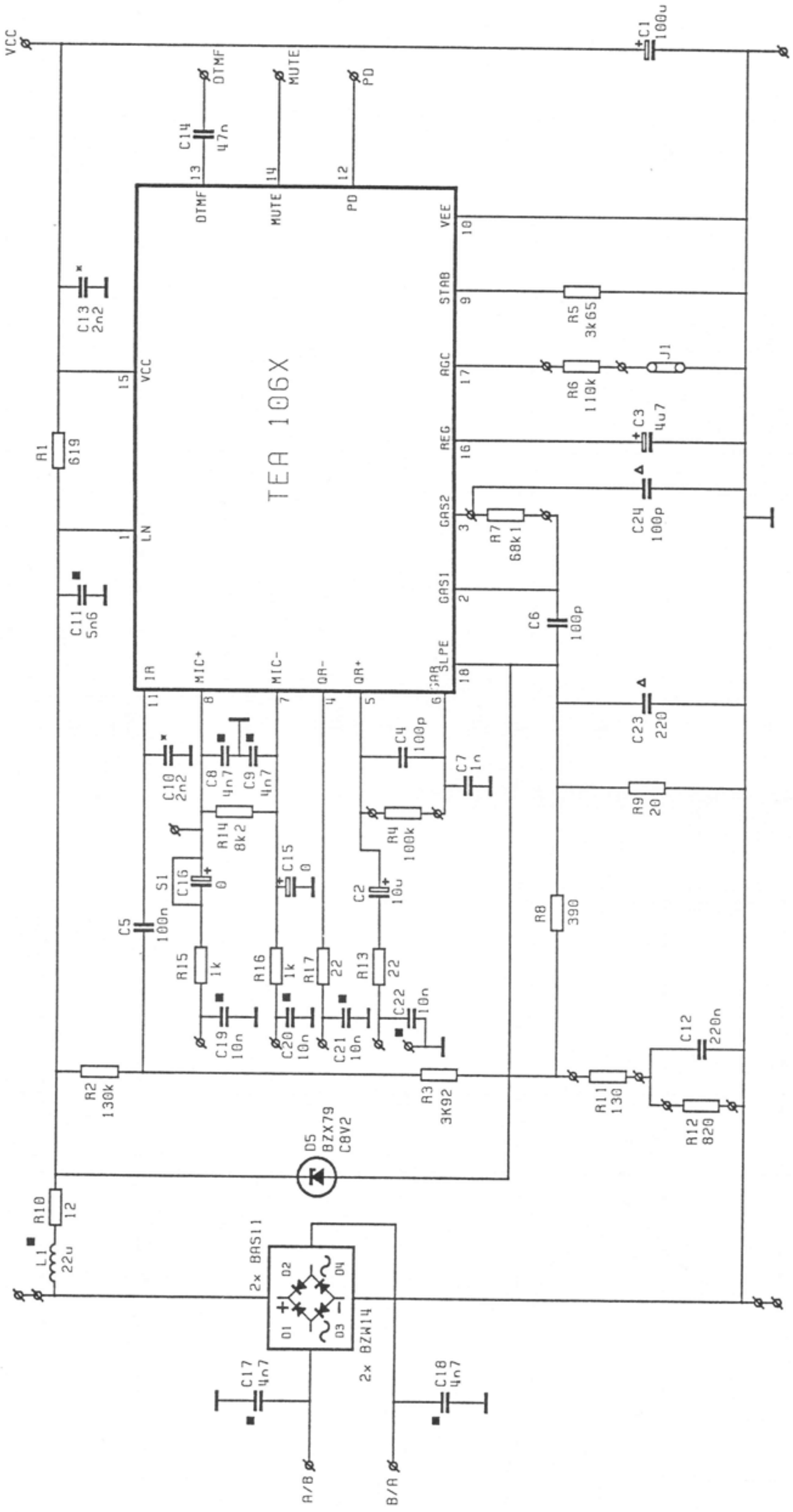
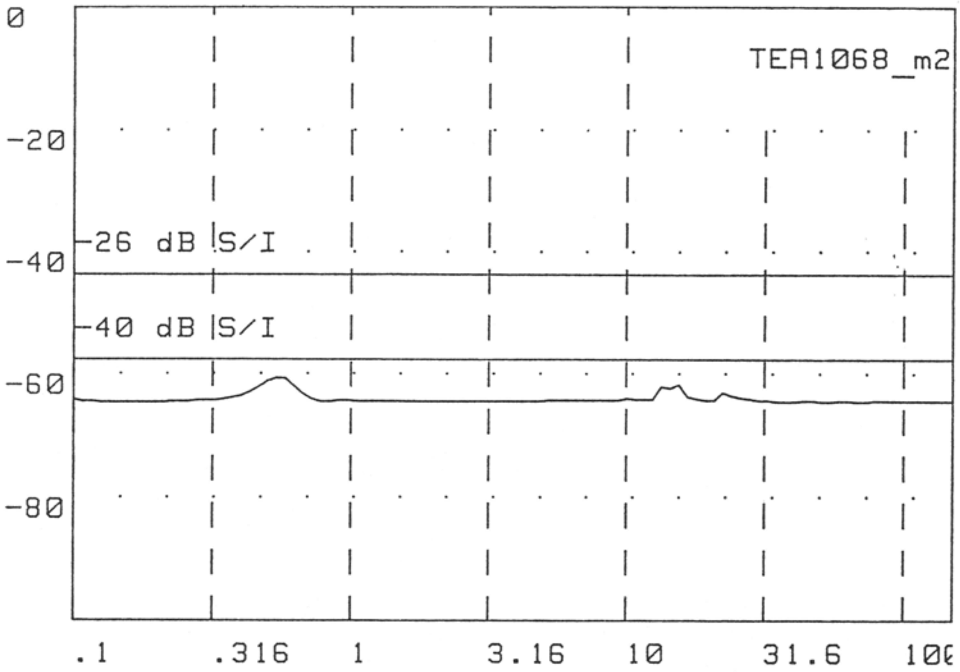


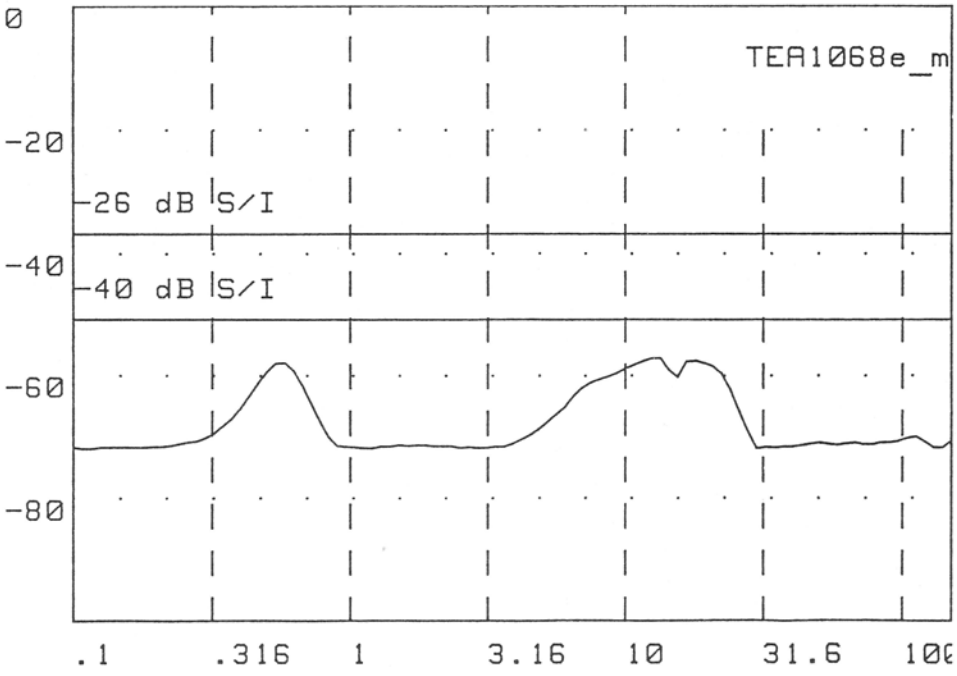
Fig. 3 CIRCUIT DIAGRAM OF PRINTED CIRCUIT BOARD CAB3391 (Mod.2)

(Note : Capacitors with capacitance 0 are not mounted.
Resistors with resistance 0 and coils with
Inductance 0 are replaced by a short.
Capacitors marked 'Δ' are used to provide enhanced EMC)

Annex 5 TEA 1060 application with 'enhanced' EMC (M2) performance (add 2 capacitors)

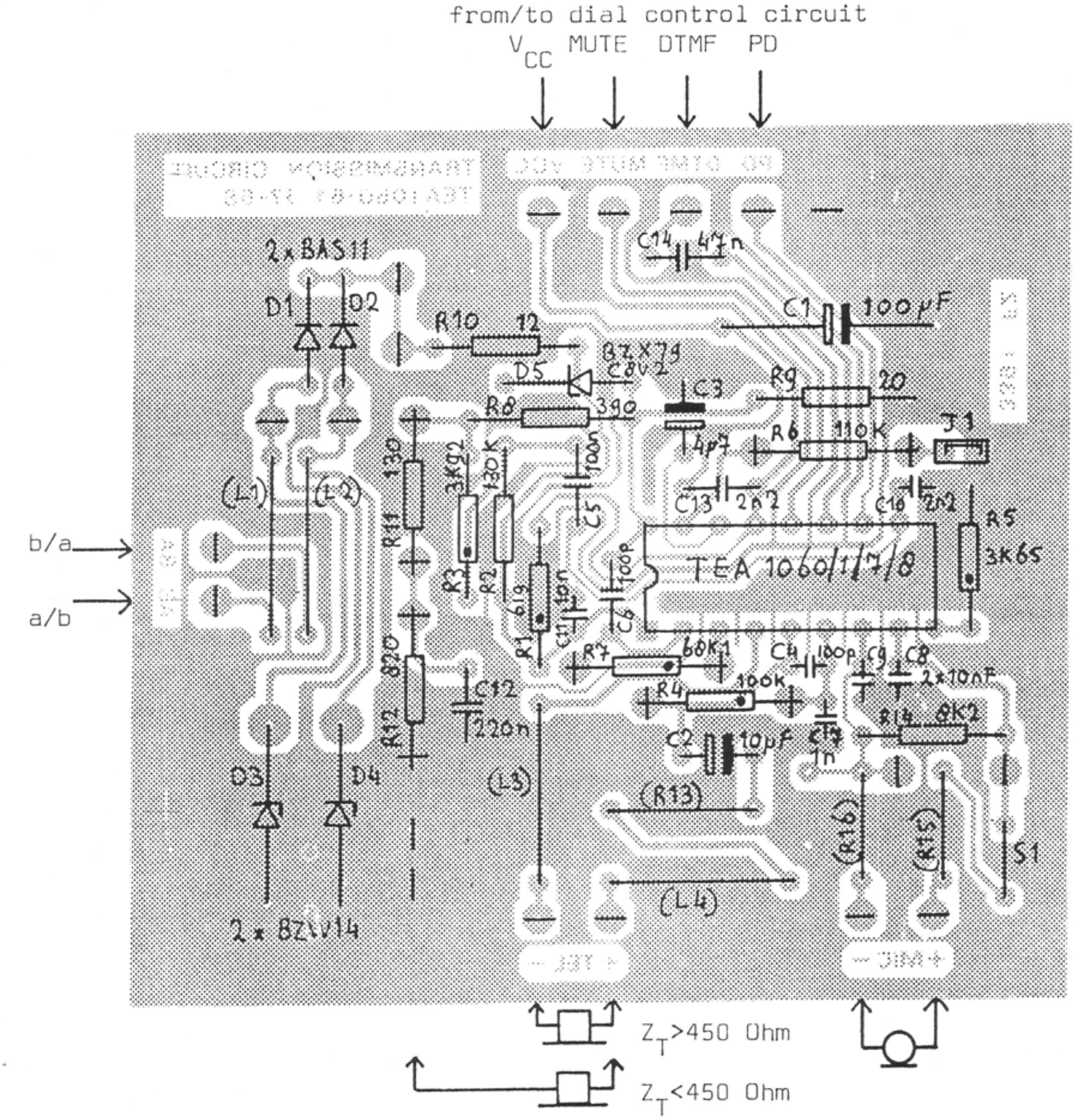


a) detection on a,b-lines



b) detection at earpiece side.

Annex 6 EMC performance of enhanced application.



Annex 7 Layout of the TEA 1060 application board CAB 3391.

Philips Components – a worldwide company

Argentina: PHILIPS ARGENTINA S.A.,
Div. Philips Components, Vedia 3892, 1430 BUENOS AIRES,
Tel. (01) 541-4261.
Australia: PHILIPS COMPONENTS PTY Ltd, 11 Waltham Street,
ARTARMON, N.S.W. 2064, Tel. (02) 439 3322.
Austria: ÖSTERREICHISCHE PHILIPS INDUSTRIE G.m.b.H.,
UB Bauelemente, Triester Str. 64, 1101 WIEN,
Tel. (0222) 60 101-820.
Belgium: N.V PHILIPS PROF. SYSTEMS – Components Div.,
80 Rue Des Deux Gares, B-1070 BRUXELLES,
Tel. (02) 52 56 111.
Brazil: PHILIPS COMPONENTS (Active Devices)
Av. Brigadeiro Faria Lima, 1735-SAO PAULO-SP,
Tel. (011) 211-2600.
PHILIPS COMPONENTS (Passive Devices & Materials)
Av. Francisco Monteiro, 702-RIBEIRO PIRES-SP,
Tel. (011) 459-8211.
Canada: PHILIPS ELECTRONICS LTD., Philips Components,
601 Milner Ave., SCARBOROUGH, Ontario, M1B 1M8,
Tel. (416) 292-5161.
(IC Products) SIGNETICS CANADA LTD.,
1 Eva Road, Suite 411, ETOBICOKE, Ontario, M9C 4Z5,
Tel. (416) 626-6676.
Chile: PHILIPS CHILENA S.A., Av. Santa Maria 0760, SANTIAGO,
Tel. (02) 77 38 16.
Colombia: IPRELENSO LTDA., Carrera 21 No. 56-17, BOGOTA,
D.E., P.O. Box 77621, Tel. (01) 249 76 24.
Denmark: PHILIPS COMPONENTS A/S, Prags Boulevard 80,
PB 1919, DK-2300 COPENHAGEN S, Tel. 01-54 11 33.
Finland: PHILIPS COMPONENTS, Sinikalliontie 3,
SF-2630 ESPOO HELSINKI 10, Tel. 358-0-50 261.
France: PHILIPS COMPOSANTS RTC-COMPELEC, 117 Quai du
Président Roosevelt, 92134 ISSY-LES-MOULINEAUX Cedex,
Tel. (01) 40 93 80 00.
Germany (Fed. Republic): VALVO, UB Bauelemente der
Philips G.m.b.H., Valvo Haus, Burchardstrasse 19,
D-2 HAMBURG 1, Tel. (040) 3296-0.
Greece: PHILIPS HELLENIQUE S.A., Components Division,
No. 15, 25th March Street, GR 17778 TAVROS,
Tel. (01) 4894 339/4894 911.
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Tel. (0)-42 45 121.
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Components Dept., Band Box Building,
254-D Dr. Annie Besant Rd., BOMBAY – 400 025,
Tel. (022) 49 30 311/49 30 590.
Indonesia: P.T. PHILIPS-RALIN ELECTRONICS,
Components Div., Setiabudi II Building, 6th Fl.,
Jalan H.R. Rasuna Said (P.O. Box 223/KBY) Kuningan,
JAKARTA 12910, Tel. (021) 51 79 95.
Ireland: PHILIPS ELECTRONICS (IRELAND) LTD.,
Components Division, Newstead, Clonskeagh, DUBLIN 14,
Tel. (01) 69 33 55.
Italy: PHILIPS S.p.A., Philips Components,
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Japan: PHILIPS K.K. Philips Components Division,
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Tel. (03) 740 5028.
Korea (Republic of): PHILIPS ELECTRONICS (KOREA) LTD.
Components Division, Philips House, 260-199 Itaewon-dong,
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3 Jalan SS15/2A SUBANG, 47500 PETALING JAYA,
Tel. (03) 7345 511.
Mexico: PHILIPS COMPONENTS, Paseo Triunfo de la Republica,
No 215 Local 5, Cd Juarez CHI HUA HUA 32340 MEXICO
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